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A decision support system for the location of Naval Surface Reserve Units

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THESIS

A DECISION SUPPORT SYSTEM FOR THE LOCATION OF NAVAL SURFACE RESERVE UNITS

by

Laura Leigh Venable

March 1998

Principal Advisor: William R. Gates

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A comparative decision model was developed based on Multi-Attribute Utility Theory. Design of a Spatial Decision Support System was proposed to incorporate a commercial mapping engine, the formal unit location decision model, and a commercial decision model solver. Since the proposed Decision Support System can provide flexibility, increase the number of decision factors considered, and reduce decision processing time, software development and construction of a Reserve unit Decision Support System prototype is recommended.

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A DECISION SUPPORT SYSTEM FOR THE LOCATION OF NAVAL SURFACE RESERVE UNITS

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Submitted in partial fulfillment
of the requirements for the degree of

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from the

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March 1998

ABSTRACT

This thesis analyzes the process needed to evaluate potential Naval Reserve unit locations from the perspective of cost, manpower, support for the active Navy, and Reserve facility support capability. The research suggests the feasibility of a PC-based Decision Support System to assist Commander, Naval Surface Reserve Force improve the effectiveness and efficiency of the unit location decision.

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ACKNOWLEDGMENT

The author would like to acknowledge the financial and research support of Commander, Naval Surface Reserve Force (N1) in sponsoring this thesis.

I. INTRODUCTION

This thesis examines the problem of efficiently and effectively determining Naval Reserve unit site location to make best use of available manpower while providing maximum support to active Navy commands. The feasibility of a personal computer (PC) based decision model is analyzed and the framework for a Spatial Decision Support System (SDSS) developed.

A. BACKGROUND

The sponsor of this research is Commander, Naval Surface Reserve Force (COMNAVSURFRESFOR), an echelon three command within the U. S. Naval Reserve Force whose mission, as specified in the Naval Reserve Force Mission Statement, is to provide "mission-capable units and individuals to the Navy, Marine Corps Team throughout the full range of operations from peace to war." To accomplish this mission, COMNAVSURFRESFOR must locate Reserve units to most effectively use all available assets, both in readiness training for mobilization and in routine support of active Navy operations.

Today, the Navy, including the Naval Reserve, faces diminishing manpower, increasing missions, and ever tightening budgets. These constraints, along with the success provided by Naval Reservists recalled to active duty for operations "Desert Shield" and "Desert Storm," have prompted active Navy commands to increasingly

call upon the Naval Reserve to actively participate in day to day operations. Additionally, much required unit and personal readiness training cannot be accomplished at Reserve centers, but requires a significant expenditure of funds to transport personnel to their active Navy gaining command. Financial assets are further strained by certain policy mandated requirements, such as providing berthing for Reservists who must travel more than fifty miles to drill at their Reserve center. Thus, locating Naval Reserve units relative to their manpower base, active Navy command, and local training availability is important both financially and for the quality of training that can be achieved.

Currently, the COMNAVSURFRESFOR unit location decision is based on narrow studies hampered by limited access to data resources and limited familiarity with the onsite commercial mapping engine (MapInfo™). Decisions are largely based on personal intuition. The cognitive abilities of the unaided, human decision maker are quickly overcome by the numerous factors that should be considered in this decision. Therefore, research to develop a systematic, flexible, convenient, and automated decision support system was launched.

B. RESEARCH OBJECTIVES

There are two objectives of this thesis. First, to determine if a PC-based decision support system to address Naval Reserve unit location is feasible. Second, given feasibility, to design a formal decision model and suggest a system architecture

for future development and implementation of a computer based Spatial Decision Support System (SDSS). Accomplishing these objectives requires analyzing the nature of the problem, identifying both the desired goals and the decision factors pertinent to each goal, selecting an appropriate decision model, determining the necessary assumptions and simplifications, identifying required databases and sources, and designing a decision model framework.

C. RESEARCH QUESTIONS

This thesis will address the following questions:

Primary Research Questions

- Is a PC-based decision support system feasible?
- How can the Naval Reserve unit location problem be structured using formal decision theory?
- What assumptions and simplifications are required to ensure a manageable yet effective model?

Subsidiary Research Questions

- What are the limitations of the model?
- How do the assumptions and simplifications affect the model's validity?

D. SCOPE, LIMITATIONS, AND ASSUMPTIONS

The scope of this thesis is driven by COMNAVSURFRESFOR's need for a flexible multi-criteria decision model capable of handling decisions with a significant

geographic component. It must be useable by decision makers and system operators who are not experts in statistical analysis or information technology. There will be frequent turnover in system operators, due to military personnel transfers; system operators will also come to the job with varying computer science backgrounds. Thus, it is important to provide a SDSS which requires little training to successfully operate.

External requirements and restrictions provided by manpower specialists at COMNAVSURFRESFOR focused the research through a set of goals. The goals in locating Naval Reserve units were: minimize contract berthing costs; minimize In Assignment Processing (IAP) personnel; minimize Cross Assigned Out (CAO) personnel; maximize peacetime support; maximize billet match; and maximize readiness. Only current Reserve centers and active Navy commands are considered potential location alternatives. The decision maker, however, can manually input other alternatives.

The proposed decision support system is not intended to provide the one correct solution to a given Reserve unit location decision or to remove the ultimate decision from the province of the decision maker. Because decision making is iterative and each individual Reserve unit location decision may involve consideration of different priorities, the system allows the decision maker to reassess preferences throughout the process.

E. METHODOLOGY

The starting point for the thesis was a meeting with COMNAVSURFRESFOR manpower specialists and senior decision makers to determine the goals to be met by the SDSS. Current unit location procedures were examined, including the data accessed and the limited use of MapInfo™.

An earlier thesis (Murphy, 1997) developing a SDSS for relocation of Army Reserve units was studied for applicability to the Naval Reserve problem. Although the factors considered and the prospective manpower base were different, similarity between the two problems made Murphy's analysis and model a useful basis from which to begin developing a SDSS for COMNAVSURFRESFOR.

F. THESIS ORGANIZATION

The thesis text proceeds as follows:

Chapter II discusses the changing military environment that requires an effective unit location decision process. Chapter III describes the fundamental components of a DSS and presents the theory and steps which led to the formal decision model presented. Chapter IV proposes a system architecture which can be developed based on the decision model presented and a similar study conducted for the Army Reserve (Murphy, 1997). Chapter V provides conclusions as to the benefits resulting from this study and recommendations for further research and action by COMNAVSURFRESFOR.

II. DERIVATION OF THE UNIT LOCATION SDSS

A. HISTORICAL PERSPECTIVE

The United States has supported a Naval Reserve since Colonial days when the Secretary of the Navy had authority to lend older ships and equipment to states with a naval militia for drills and instruction. However, Congress formally created a "Federal Naval Reserve" in 1915. As of February 1998, the Naval Reserve Force had 219,733 personnel in the Ready Reserve; 125,984 in the Individual Ready Reserve (IRR) and 93,704 in the Selected Reserve (SELRES). The Selected Reserve, the primary mobilization manpower pool, is divided into two components: the Naval Surface Reserve Force and the Naval Air Reserve Force. Commander, Naval Surface Reserve Force (COMNAVSURFRESFOR) has cognizance over 59,833 men and women, 24 Naval Reserve Force Ships, 10 Naval Reserve Readiness Commands, 167 Reserve Centers, and 2010 Reserve units including Mobile Inshore Undersea Warfare units, Naval Reserve Cargo Handling Battalions, Naval Reserve Fleet Hospitals, Special Boat Units, and numerous augment units that support a vast diversity of active Navy commands.

The performance of the over 20,000 Naval Reservists recalled to active duty for Operations "Desert Shield" and "Desert Storm" (1990-91), proved that the Naval Reserve was not just a drill and instruction organization but a vital asset and force

multiplier to the Navy and Marine Corps team. Active Navy commands became aware of a pool of talent that had for the most part previously been untapped.

With increasing missions, a tightening federal budget, and downsizing of the military, both active and Reserve, active Navy commands began calling on the Naval Reserve for greater peacetime contributory support to meet day to day operational requirements. The Naval Reserve Force has demonstrated an awareness of and determination to meet this new mandate in its mission and vision statements published in the Naval Reserve Force Strategic Plan.

Mission Statement

The Naval Reserve provides mission-capable units and individuals to the Navy, Marine Corps Team throughout the full range of operations from peace to war.

Vision Statement

The Naval Reserve is a highly trained, well equipped and fully accessible combat-ready force with a world-class reputation for professional excellence. We are responsive and provide a broad range of cost effective, adaptable military capabilities and civilian skills to fulfill mission requirements.

B. UNIT LOCATION DECISION

While every decision has its own particular problems, there are four general reasons why effective decision making may be difficult. First, a decision may be difficult because of complexity. The range of issues may involve too much information to process simultaneously and overpower the decision maker's cognitive ability. Second, a decision may be difficult because there are multiple

objectives and success toward one objective may limit success in others. There is a need for the decision maker to weigh the costs and benefits of any action. Third, a decision may be difficult because different perspectives on the decision may result in different conclusions. This is especially problematic when there is more than one stakeholder or decision maker involved. Finally, a decision may be difficult because of situational uncertainty. (Clemen, 1996)

Any decision that involves one or more of these sources of difficulty can be more effectively made by applying decision analysis. Decision analysis improves the quality of decisions by helping the decision maker examine the problem in a more systematic manner. This is accomplished by breaking the problem down into component pieces that can be more easily analyzed. Those pieces are then reconstructed to give a clearer overall picture of the decision situation.

The Reserve unit location decision meets the criteria for a decision that can be improved by decision analysis. Each year, COMNAVSURFRESFOR must manage significant force structure changes in the ongoing effort to meet the Navy's needs. Ships are commissioned and decommissioned. Claimants and resource sponsors must deal with new mission requirements or changes in resource priorities. All such occurrences have an impact on the Naval Reserve force structure. New Reserve units may be established, each with specific

manpower requirements. Other units may be disestablished, leaving a pool of personnel who no longer fill a mobilization billet. Still other units may need to be relocated.

Each unit location decision is extremely complex involving the needs of the active Navy gaining command along with the realities of the Reserve environment such as actual manpower availability and funding constraints. Active Navy commands, as stakeholders, have moved to increase their influence in the decisions involving their augment units. Their perspective is different from the Naval Reserve decision maker who must be cognizant of more than just the peacetime support needs of the gaining command. As a consequence, objectives may be in conflict.

The result is that the decision maker is currently limited by a process that is mainly intuitive and cumbersome, taking anywhere from 35 to 60 days or more. Many factors that would be useful in making an effective decision are disregarded because they are too numerous and complex for unaided human cognitive ability. The only automated data access is an interface between MapInfo™ and the Reserve Training Support System (RTSS) to derive spatial data. While this data is valuable, the system is not user friendly, often making the data inaccessible to the decision maker in any usable format.

COMNAVSURFRESFOR needs a Reserve unit location decision system that meets the following criteria:

- Results in a more effective decision
- Allows consideration of numerous factors affecting the quality of the decision
- Requires little training to achieve satisfactory results (i.e., user friendly)
- Provides flexibility, allowing the decision maker to redefine the alternatives and preferences throughout the process
- Shortens processing and evaluation time.

A Spatial Decision Support System (SDSS) incorporating decision analysis can be used to satisfy these criteria.

C. COMNAVSURFRESFOR REQUIREMENTS

A meeting with COMNAVSURFRESFOR manpower specialists established the requirement to develop a PC-based computer system for determining the best site location for Naval Reserve units. Six sub-objectives were also identified to be included in the decision process:

- Minimize contract berthing costs. Personnel who reside over 50 miles from their drill site receive government funded berthing while attending drills. Berthing costs will vary from Reserve center to Reserve center depending on the availability of berthing at area military bases or the price range of the local hotel market.

- Minimize In Assignment Processing (IAP) personnel. IAP personnel drill for pay but are not assigned to mobilization billets. These individuals need to be assigned to unit billets to increase their training and peacetime support opportunities and to ensure the taxpayers a return on their investment.

- Minimize Cross Assigned Out (CAO) personnel. CAO personnel drill with a unit at a Reserve center near their residence while actually being assigned to a unit at a distant Reserve center. This occurs when there is no unit with an available billet they can fill within a reasonable commuting distance. Being a CAO driller, rather than a local driller, makes receiving required billet training much more difficult.

- Maximize peacetime contributory support. Active Navy commands are looking to the Naval Reserve to provide more than mobilization assets in time of crisis. They are requesting more support for day to day routine operations.

- Maximize unit billet match. Billets need to be filled with individuals who exactly match the rate and rating or rank and designator of the billet.

- Maximize readiness. Individual and unit readiness need to be achieved. Although not always the case, the need for readiness training can conflict with peacetime support.

D. CHAPTER SUMMARY

Increased global commitments and decreased assets in both personnel and equipment are creating ever growing demands for the Naval Reserve to provide support for the active Navy's day to day operations. COMNAVSURFRESFOR must balance the peacetime contributory support requirements with the continuing mandate to ensure that SELRES are trained, equipped, and combat-ready, both

individually and as units. The ability to successfully accomplish these mandates is strongly influenced by the location of the SELRES unit. Current procedures for determining unit location are not sufficient because they rely primarily on unaided human cognitive ability, which is not capable of simultaneously processing all the decision factors that should be considered. A SDSS utilizing decision analysis will provide the decision maker with the tools necessary to improve the quality of the resulting decisions.

III. DEVELOPMENT OF A DECISION SUPPORT SYSTEM

A. NATURE AND USE OF A DSS

The typical starting point from which to understand any concept is its accepted definition. This is not easily achievable with DSS. For several decades, scholars have conducted DSS research, discussed DSS at conferences and in working groups and failed to arrive at a universally accepted definition that satisfactorily covers all aspects of a DSS.

A DSS can, perhaps, best be understood by examining its purposes, characteristics, and components. Samuel Bodily (1985) suggests the following way of thinking about a DSS:

> Think of the complete DSS as a high-level language that allows for natural, English-like expression of the model; that is able to access corporate and vendor data bases; that has easy-to-use graphics for displaying the results; and that contains powerful computational features for activities such as 'what-if,' sensitivity analysis, goal seeking, extrapolation, risk analysis, and optimization. In addition, think of the DSS as a system that supports the manager in treating ill-structured, messy problems and extends and enhances the manager's own understanding and judgement rather than providing a unique solution.

The emphasis is on "increased individual and organizational effectiveness rather than on increased efficiency in processing masses of data" (Alter, 1980).

The purpose of a DSS is to improve the quality of decisions, not to remove the human decision maker from the process. A DSS allows the decision maker to

view the data in an easily comprehendible format and provides the flexibility for element and preference changes based on decision maker judgement.

A well developed DSS has the following characteristics:

- Solves problems that would *not* be amenable to management science optimization models per se;
- Provides support for decision makers in semistructured situations by bringing together human judgement and computerized information;
- Is an interactive, flexible, and adaptable computer-based information system;
- Utilizes decision rules and models coupled with comprehensive databases;
- Utilizes the decision maker's own experiences and insights;
- Is customized to the attributes of the individual decision makers;
- Yields specific, implementable decisions;
- Is adaptive over time; and
- Is easy to use. (Thomas, Murphy, and Dolk, 1997)

Three components commonly comprise a DSS: data, models, and a user interface (Sprague and Carlson, 1982). Making up the data component is a database, database management system (DBMS), a database dictionary, and a method of query. The model component includes a model base and management

system along with a directory and mode of executing the model. The interface ties the other two components together and the operator into the system.

B. DEVELOPMENT OF THE DECISION MODEL

The usefulness of a DSS centers around developing a decision model which is a quantitative or logical abstract of reality created to sort out, arrange, and simplify the complexities of a problem. It assists the decision maker in evaluating potential solutions or in predicting certain outcomes if a particular alternative is implemented.

A model can be predictive, normative, or prescriptive. The predictive model is developed for use in forecasting the future, such as models dealing with national economic issues. Normative models assist in identifying solutions, showing what can be done to achieve required objectives. Prescriptive models assist in determining the best solution based on measures important to the decision maker. (Gass, 1985) The unit location model is a prescriptive model.

1. Identifying the Decision and Alternatives

Figure (1) shows a flowchart for the decision analysis process (Clemen, 1996). Two steps must occur before the decision model is developed. The decision situation and objectives must be identified and understood and the alternatives must be identified.

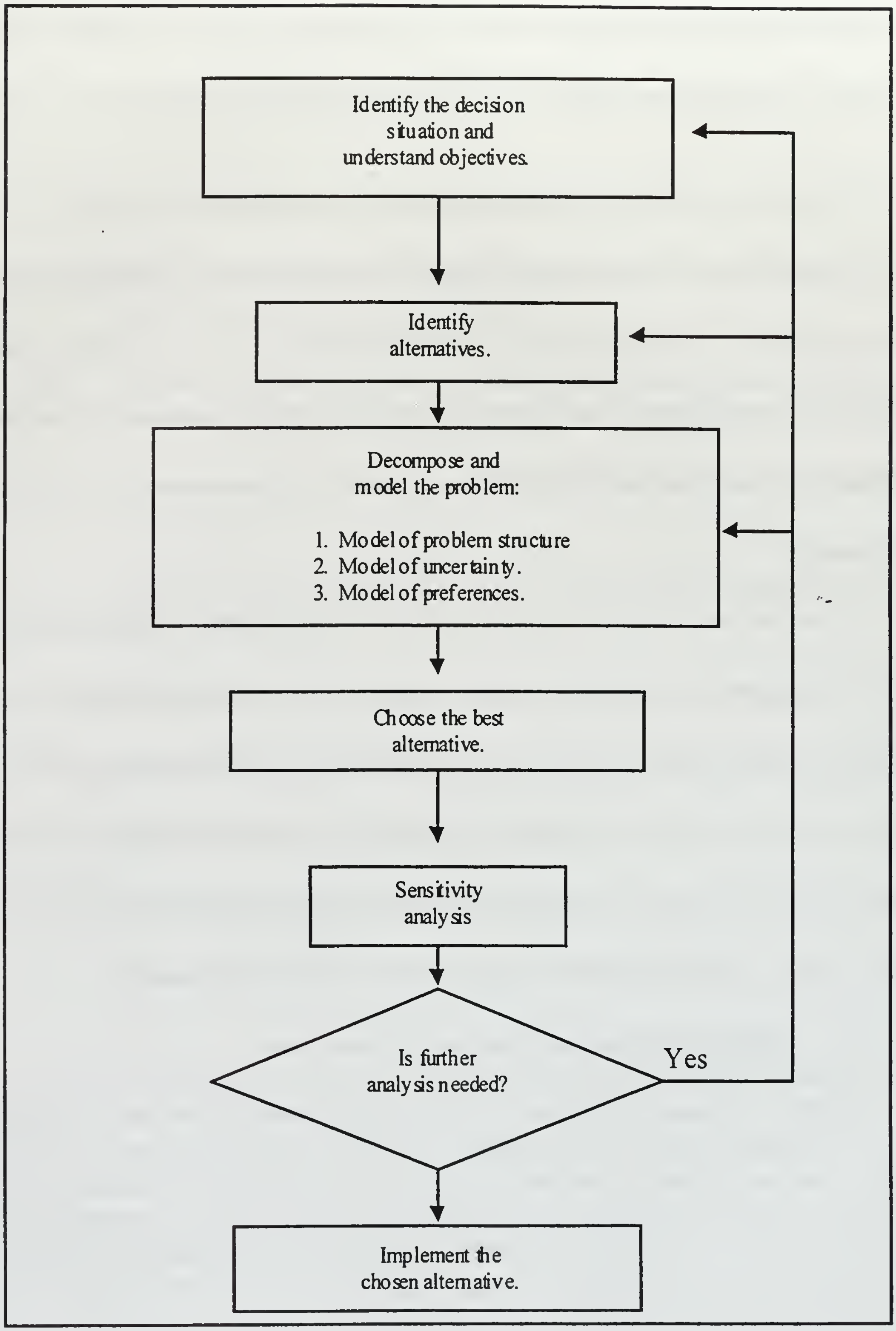

Figure 1. A Decision-Analysis Process Flowchart (Clemen, 1996)

To accomplish these steps for the Reserve unit location problem, a meeting was held with COMNAVSURFRESFOR manpower specialists to discuss the decision situation and determine the objectives involved. From that meeting evolved the overall goal of designating the best unit location. A discussion of what is important to achieving the overall goal resulted in the following objectives:

- Minimize contract berthing costs
- Minimize In Assignment Processing (IAP) personnel
- Minimize Cross Assigned Out (CAO) personnel
- Maximize peacetime support
- Maximize unit billet match
- Maximize readiness.

The unit location alternatives were identified as the 167 Naval Reserve centers plus the unit's active Navy gaining command.

2. Constructing a Hierarchy of Goals

Several factors went into choosing a Multi-Criteria Decision Model (MCDM) for the unit location problem. First, the decision involves a number of objectives. Second, those objectives could conflict. Third, it is unlikely that a single alternative will achieve best performance under all of the objectives (i.e.,

dominant solutions), so it is necessary to examine the trade-offs between the benefits of various alternatives.

MCDM creates a hierarchy of goals by decomposing the objectives, which are typically qualitative, through an iterative process, until they are specific enough to be measured in a quantitative fashion. In much of the decision analysis literature, the qualitative elements of the hierarchy are called objectives and the quantitative ones are called attributes. However, Logical Decisions for Windows™ (LDW), the commercial software chosen for model development and use in the evaluation phase of the DSS, refers to objectives as goals and attributes as measures. That is the terminology which will be used throughout the remainder of this thesis.

The hierarchy of goals makes it easier to identify the objective inputs required for the decision model. Required objective input identification, in turn, helps the decision maker determine if existing databases can supply the needed data or if new databases should be created. In addition, the level of required system operator manual input can be ascertained.

The initial step taken in constructing a hierarchy of goals is generating a basic utility function for the COMNAVSURFRESFOR overall goal, which considers the specified sub-goals. Utility is the common scale used to measure desirability or preference. It represents the value a decision maker places on the

outcome and depends on a decision maker's preference for each measure in relation to the others. The utility or desirability afforded by a particular unit location was determined to be a function of cost, unit fill, peacetime support, and facility support capability (U=f(cost, unit fill, peacetime support, facility support capability)). Each of these four elements was further decomposed, resulting in the hierarchy of goals shown as Figure (2).

Finally, the screening criteria for each measure were identified. The screening criteria will be used in developing the DSS software that queries the source databases. The hierarchy of goals with screening criteria is shown in Figure (3).

3. Determining Preferences

The hierarchy of goals provides the framework within which decision maker preferences can be further analyzed and modeled. LDW provides seven techniques to accomplish this analysis. The technique chosen for the unit location decision is the Simple Multi-attribute Rating Technique (SMART) or "swing weights" method.

SMART requires the decision maker to assign a utility function for each measure to assess the alternatives' performance on each measure. For this purpose, the Single-measure Utility Function (SUF) uses a continuous function

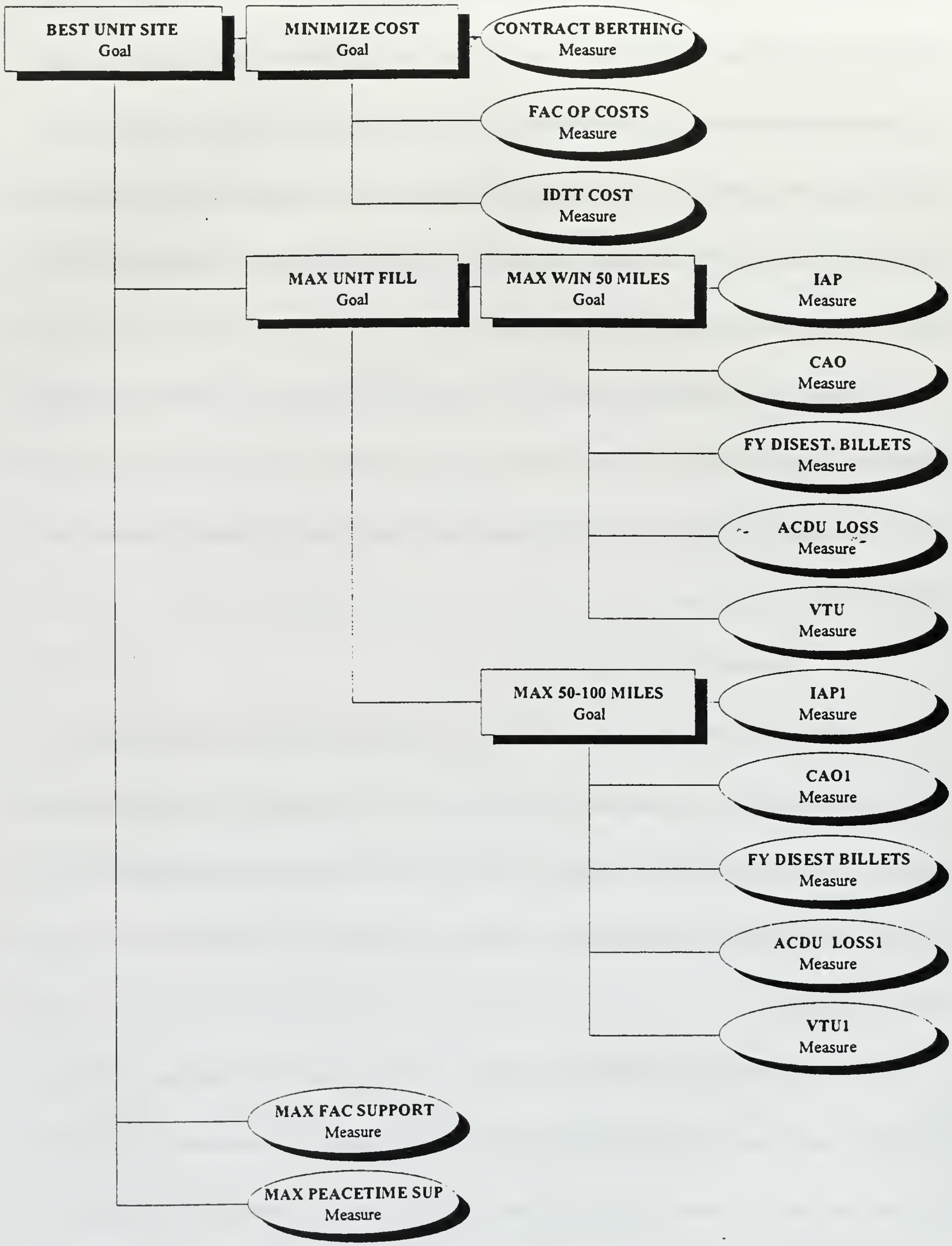

Figure 2. Hierarchy of Goals

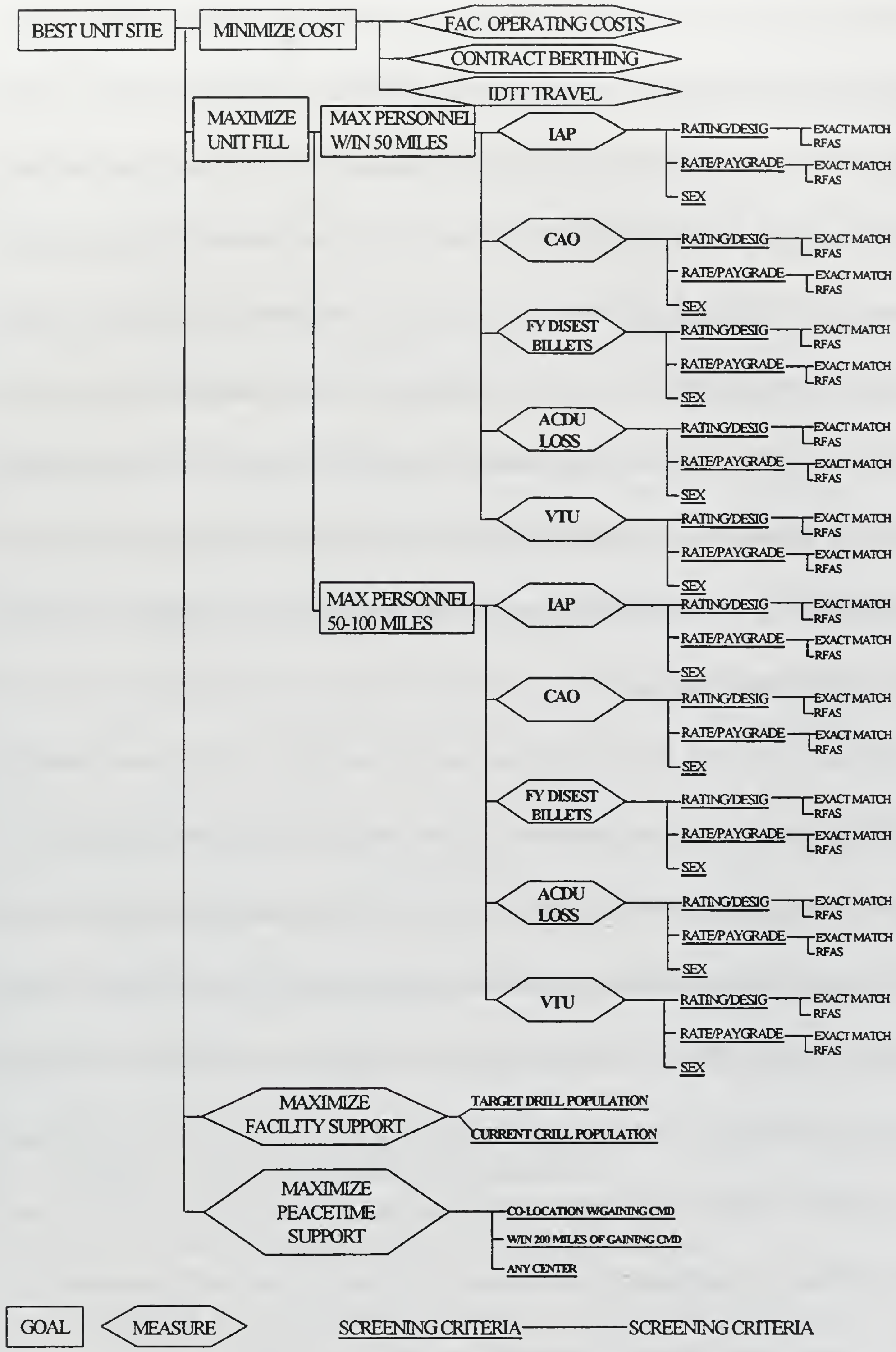

Figure 3. Hierarchy of Goals with Screening Criteria

to convert the measure's nominal scale levels to utility. Assigning a utility of zero for the least-preferred level and a utility of one for the most-preferred level, SUF calculates a utility estimate for any level in between. One of the most widely applied methods for accomplishing this is bisection or mid-level splitting. The decision maker identifies the level that is midway in importance, in other words, represents an equal change in utility between the most-preferred and least-preferred level. That mid-level point need not be the average of the range ends. If desired, the measure range can be further subdivided to model the decision maker's preferences. Once the preference levels are established, LDW computes the SUF curve automatically.

Following this, the decision maker assigns weights to the measures and goals reflecting their relative importance. While the decision maker could directly attach a weight to each measure, this would not take into account the size of the range between the least-preferred and most-preferred level of each measure. By using swing weights, SMART forces the decision maker to compare a change from the least-preferred to most-preferred level of one measure with a similar change in another measure. This approach compensates for range variations, yet does not significantly complicate the responses required by the decision maker, as compared to direct assignment. (Goodwin and Wright, 1991)

Generally, the swing weight process as implemented by LDW proceeds as follows: an alternative is assumed to have all of its member goals and measures at the least-preferred level. The decision maker determines which member would be improved to the most-preferred level if only one could be improved. That member is assigned a weight of 100. Then the decision maker decides the importance of swinging each other member from the least-preferred level to the most-preferred level as a proportion of the first measure. For example, if improving the second measure is only half as important as the first, it would be assigned a weight of 50. This same determination is made for each member until all have been ordered and assigned weights. LDW adjusts the weights so they sum to one.

The additive utility function, which is simply a weighted average of the other utility functions, is computed for each alternative. LDW then provides a ranking of all the alternatives. Sensitivity analysis can be performed to determine the effect of changes in the importance of measures and goals.

C. MODEL ASSUMPTIONS AND ISSUES

1. General Assumptions and Simplifications

A model is a representation of reality used to understand and analyze a complex problem. Models often require numerous simplifications and assumptions

to limit complexity, yet it is important that they remain accurate enough to be used in place of the actual situation.

The general assumptions and simplifications applied to the unit location model include:

- Reserve unit location will have little or no influence on where people choose to live. People will not move just to be closer to the unit or relocate when the unit does. (Murphy, 1997)

- The area of the alternative site refers to the region within 100 miles of the Reserve center or active Navy gaining command. It is assumed that anyone outside that region will have no impact on the unit since there is no way to determine with any consistency how many people from a greater distance would be willing to participate in the unit.

- Distances are straight-line calculations. No allowance is made for actual travel distance based on road patterns.

- The Individual Ready Reserve (IRR) is not considered a potential manpower pool. A significant portion of the IRR is composed of those who are ineligible to drill in a pay status; who have no desire to drill or are unable to drill due to personal hardship; or who have been transferred to the IRR due to unsatisfactory drill participation.

- Recruiting is not a controllable measure. The recruit market only acknowledges the potential in the area. It does not determine the probability of a person joining the Naval Reserve or consider the effectiveness of various recruiters. Additionally, it does not factor in the local job market that is in competition with the Naval Reserve for a person's free time.

- Many measures are based purely on numbers of people without considering the differences made by individuals in readiness contributions or peacetime support. For example, two locations that can fill the same number of unit billets are equivalent regardless of which billets are filled or which individuals fill them.

2. Specific Assumptions and Issues Pertaining to Goals and Measures

As the hierarchy of goals was developed, certain specific assumptions were made about individual goals and measures. This section explains those assumptions and discusses issues important to each goal and measure.

a. Unit Fill

The goal to maximize unit fill encompasses four objectives originally specified by COMNAVSURFRESFOR, namely: minimize IAP; minimize CAO; maximize billet match; and maximize readiness. Of these, readiness was the most difficult to frame and quantify. The factors that impact both unit and individual readiness are numerous and often by their very nature non-tangible, such as leadership and individual talents. The training requirements of each unit are varied and the training opportunities available at each Reserve center or in the local area, while measurable, involve too complex a data collection regime to be useful. No readily accessible database of information is available. Rather, manual cataloging would be required of all special training equipment available at each of the 167 Reserve centers along with cataloging of all potential training at area colleges, military bases and stations, military and VA hospitals, and the like. The return would not equal the effort required. Even if such a database was developed, the quality of each training event would be extremely difficult to measure, thus requiring an assumption that all training had the same value.

This model takes the simplified approach that greater unit fill provides greater readiness. It is assumed that all Reservists make an equal contribution to readiness. It is also assumed that each billet is of equal importance. Therefore, two locations that can fill the same number of unit billets within the unit are considered equal in readiness, even if they do not fill the same billets.

The goal to maximize unit fill was decomposed into two sub-goals; maximize personnel within 50 miles of the Reserve center and maximize personnel between 50 and 100 miles from the Reserve center. This accounts for the difference in the Naval Reserve's cost of supporting Reservists who live outside a 50 mile radius of the drill site. As stated in the general assumptions, it is assumed that anyone living outside the 100 mile radius has no impact on the decision; it is difficult to accurately estimate the number of people willing to travel greater distances to drill.

b. Measures of Unit Fill

The sub-goals of unit fill are each comprised of the same five measures. These measures describe the potential manpower pool from which the unit may be filled. All except those personnel recently released from active duty are extracted from the Reserve Training Support System (RTSS) database. Potential prior active duty recruits are extracted from the Defense Manpower Data Center (DMDC) Active Duty Loss Record provided to the Naval Reserve Recruiting Command.

Because of the limited demand for non-prior service people in the Naval Reserve, the general recruit market was not included in the model. Should the decision environment change, such that this manning source becomes more significant, the model can be appropriately adapted. Further research would be needed in this area.

c. Measures of Cost

Measures under the minimize cost goal indicate the cost to support a unit at a particular location. Although all three measures are in common dollar units, the criteria are different (i.e., annual costs, weekend costs, trip costs). MCDM using Multi-attribute Utility Theory (MAUT) is designed to accommodate dissimilar units such as these but the decision maker needs to be cognizant of these differences when assigning relative weights to the measures.

(1) **Facility Operating Costs.** This measure indicates the annual operating cost, in dollars per square foot, for the drill facility. This data was originally created for the Base Realignment and Closure Commission (BRAC) and is not updated on any regular basis. Although available in hard copy, no automated database could be located. Consequently, the data need to be entered into the DSS manually by the system operator. To maintain the validity of this measure, updated information from the Reserve centers needs to be collected and entered into the DSS annually.

(2) **Contract Berthing**. This measure indicates the total expected cost, in dollars per drill weekend, to berth Reservists who drill at a site over 50 miles from their residence. Distance is determined using the centroid of residence and Reserve center zip codes. This introduces a certain amount of inaccuracy into the measure, since a person living on the edge of a zip code area may not belong in the distance category computed by using the zip code centroid. The amount of inaccuracy involved, however, was not considered significant for the purpose of this model and does not invalidate the measure as a useful means of location comparison.

No automated database of Reserve center berthing costs was located. Berthing contracts are awarded on an annual basis. Berthing cost data need to be requested from the Reserve centers annually and manually entered in the DSS.

(3) **Individual Training Travel (IDTT) Costs.** This measure indicates the expected cost, in dollars per person per trip, for a SELRES to travel to the active Navy gaining command for training or peacetime support, instead of participating in normal drills at the Reserve center. Currently, Reserve centers manually estimate these costs using the monthly Official Airline Guide (OAG). There are, however, several online services that the DSS could access to extract the required data, thus avoiding the need for manual input by the system operator.

d. Peacetime Support Measure

This measure indicates the opportunity a unit has to provide peacetime contributory support to its active Navy gaining command on a routine basis. This is derived by the distance from the unit location to the active Navy command, and the importance the decision maker attaches to various distances.

e. Facility Support Measure

This measure indicates the ability of a Reserve center to support the increased drill population created by the assignment of a new Reserve unit. The determination is based on the current and target drill population, which is available in hard copy, but for which no automated database could be located. Because most new or relocated Reserve units will be manned primarily by personnel already drilling at the center (i.e., IAP, CAO, VTU), this measure will seldom be applied. It is left in the model for use when a unit is established that depends largely on recruiting new personnel for unit manning (e.g., augment unit for USS John F. Kennedy requiring a significant number of seamen). The decision maker determines when this measure will be applied and the importance it will be given through the weighting scheme.

D. CHAPTER SUMMARY

A DSS is a flexible quantitative or logical abstract of reality that brings together human judgement and computerized information in a way that improves the quality of decisions by allowing the decision maker to view the data in an easily

comprehendible format. A DSS is made up of three components: data, models, and a user interface. Central to the evaluation phase of a DSS is the development of a decision model which decomposes a decision until it can be expressed as a hierarchy of goals and their attendant measures.

The hierarchy of goals for Reserve unit location was developed based on the objectives specified by COMNAVSURFRESFOR manpower specialists. The significant assumptions and simplifications required to produce a manageable model were explained and the needed and available data resources were described.

IV. PROPOSED SYSTEM ARCHITECTURE

Specification of the precise architecture for the Reserve unit location DSS requires research in information technology and software design that is beyond the scope of this thesis. The purpose of this chapter is to present a general overview of DSS phases and to explain how the decision model, commercial software, and data merge in the DSS. The design proposed is based on "ARIES: Army Reserve Installation Evaluation System," a DSS working prototype developed for the Army Reserve (Thomas, Murphy, and Dolk, 1997). The expectation is that this thesis will be the groundwork for software design research and construction of a Naval Reserve unit location DSS prototype.

A unit location evaluation session involves extracting, filtering, and processing a large amount of data from various sources. For ease of use, most of the data manipulation should be transparent to the decision maker and system operator requiring only minimal inputs. An evaluation session, when decomposed, proceeds through three basic phases described herein.

A PREPROCESSING PHASE

The primary purpose of the preprocessing phase is data extraction. This limits the data accessed during the processing phase to only that which is unique to a

specific task, thus reducing processing time. During the preprocessing phase the data are converted to a single format to prepare for the processing phase.

B. PROCESSING PHASE

During the processing phase, data are manipulated to create a measures table containing the values for the decision model measures. Spatial filtering based on distance occurs using MapInfo™. Although other commercial mapping engines are available, MapInfo™ is recommended because it is already owned by COMNAVSURFRESFOR and in limited use within the manpower directorate. MapInfo™ reduces the data handled in the DSS by eliminating all records for people residing over 100 miles from a Reserve center. The measures table output is imported into LDW for use in the evaluation phase.

C. EVALUATION PHASE

In the evaluation phase, using a commercial decision model solver, the processed objective input data are analyzed based on the decision factor preferences designated by the decision maker. Logical Decisions for Windows™ (LDW) was selected as the decision model solver after reviewing the "Decision Analysis Survey" in the August, 1996 edition of *ORMS Today* and research into the justification for its use in ARIES. The documentation for ARIES cites flexibility and implementation of the Multi-attribute Utility Theory (MAUT) decision framework as major reasons for

adopting LDW. Since these same concerns are vital to the Naval Reserve unit location model, LDW is a rational choice. Logical Decisions is about to begin beta testing a 32-bit version of LDW. This should facilitate integration with other software packages, resolving many limitations associated with the current 16-bit architecture.

The evaluation phase gives the decision maker and systems operator access to numerous displays for data analysis, model and preference modification, and sensitivity analysis. The following subsections describe the displays that are likely to be of greatest use to the decision maker.

1. Matrix Display

The "Matrix view" displays the alternatives and measures in a spreadsheet. This helps verify the decision model input for each alternative. An example of seven Reserve center alternatives and four of the 15 measures used in the Reserve unit location model are shown in Figure 4.

	IAP	CAO	FY DISEST. BILLETS	ACDU LOSS
NMCRC BILLINGS	0	0	0	1
NMCRC BOISE	0	2	0	0
NMCRC PORTLAND	4	0	1	1
NMCRC SACRAMENTO	1	3	0	1
NMCRC SALT LK CTY	10	5	0	0
NMCRC SAN JOSE	4	1	0	1
NRC EVERETT	1	0	0	1

Figure 4. Matrix View

2. Results Display

The analysis completed in the evaluation phase ranks the overall desirability of alternative Reserve centers. Figure 5 shows a black-and-white example of the multi-colored Stacked Bar Ranking produced by LDW. The length of the bar for each alternative is proportional to its utility as Best Unit Site. The segments of each bar

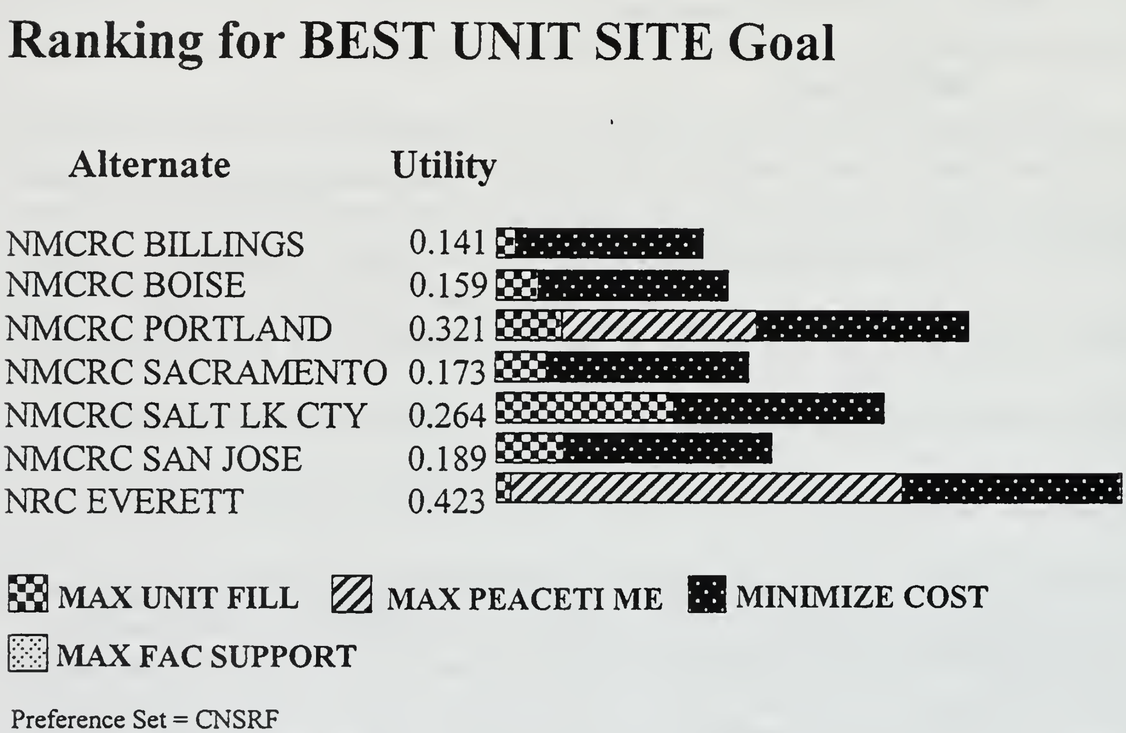

Figure 5. Goal Based Stacked Bar Ranking Display

represent the goals and measures directly under the ranked goal in the hierarchy of goals. They illustrate the contribution made by each measure, or performance under each goal, to an alternative's overall utility.

Figure 6 shows a black-and-white representation of the multi-colored Stacked Bar Ranking with the contribution made by each measure. The length of the bar for

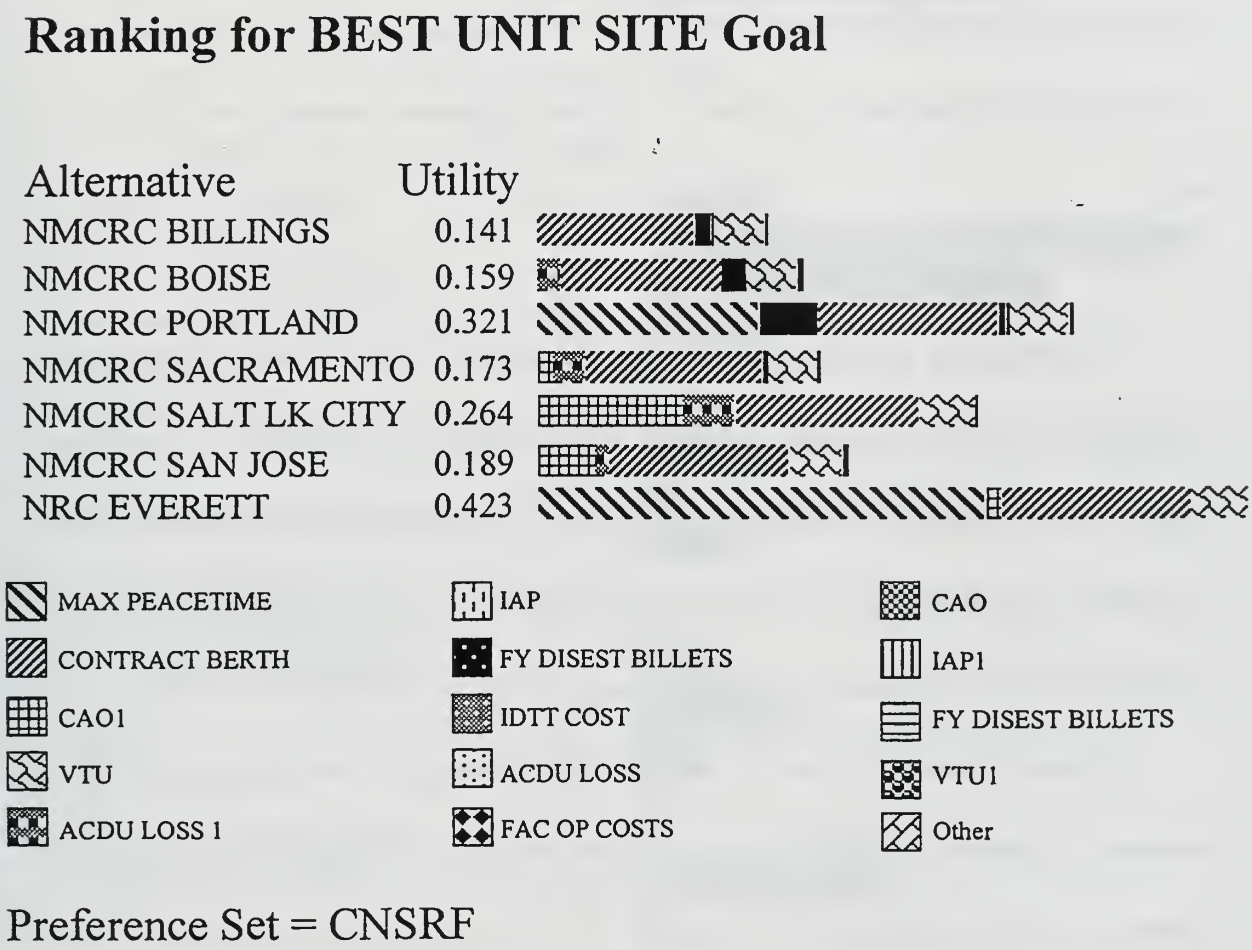

Figure 6. Measure Based Stacked Bar Ranking Display

each alternative is proportional to its utility as Best Unit Site. The overall bar is composed of color coded segments which represent the influence of each measure on the overall result. In either Stacked Bar Ranking display, a long segment means the associated goal or measure is important and the alternative exhibits significant utility in that goal or measure. Likewise, a small segment means the associated goal or measure is relatively unimportant or the alternative exhibits little utility in that area. Not all alternatives will have segments in their stacked bar for every goal or measure. An alternative will not have a segment for a goal or measure where it has a utility of zero.

3. Sensitivity Analysis

The sensitivity analysis options provided by LDW permit the decision maker to identify the effect of changes in the weight of goals and measures on decision results. LDW allows both automatic and dynamic sensitivity analysis. Using either a sensitivity graph display or a revised weight table, automatic sensitivity analysis shows the effect of changes in the importance of a particular measure or goal.

Dynamic sensitivity permits interactively changing the weights of goals and measures to conduct a "what if" analysis of the overall goal. Figure 7 shows a sample dynamic sensitivity display. The display is divided into two panes; an upper pane which shows the current overall utilities for the alternatives and a lower pane which shows the weights for the goals and measures. The decision maker can adjust the

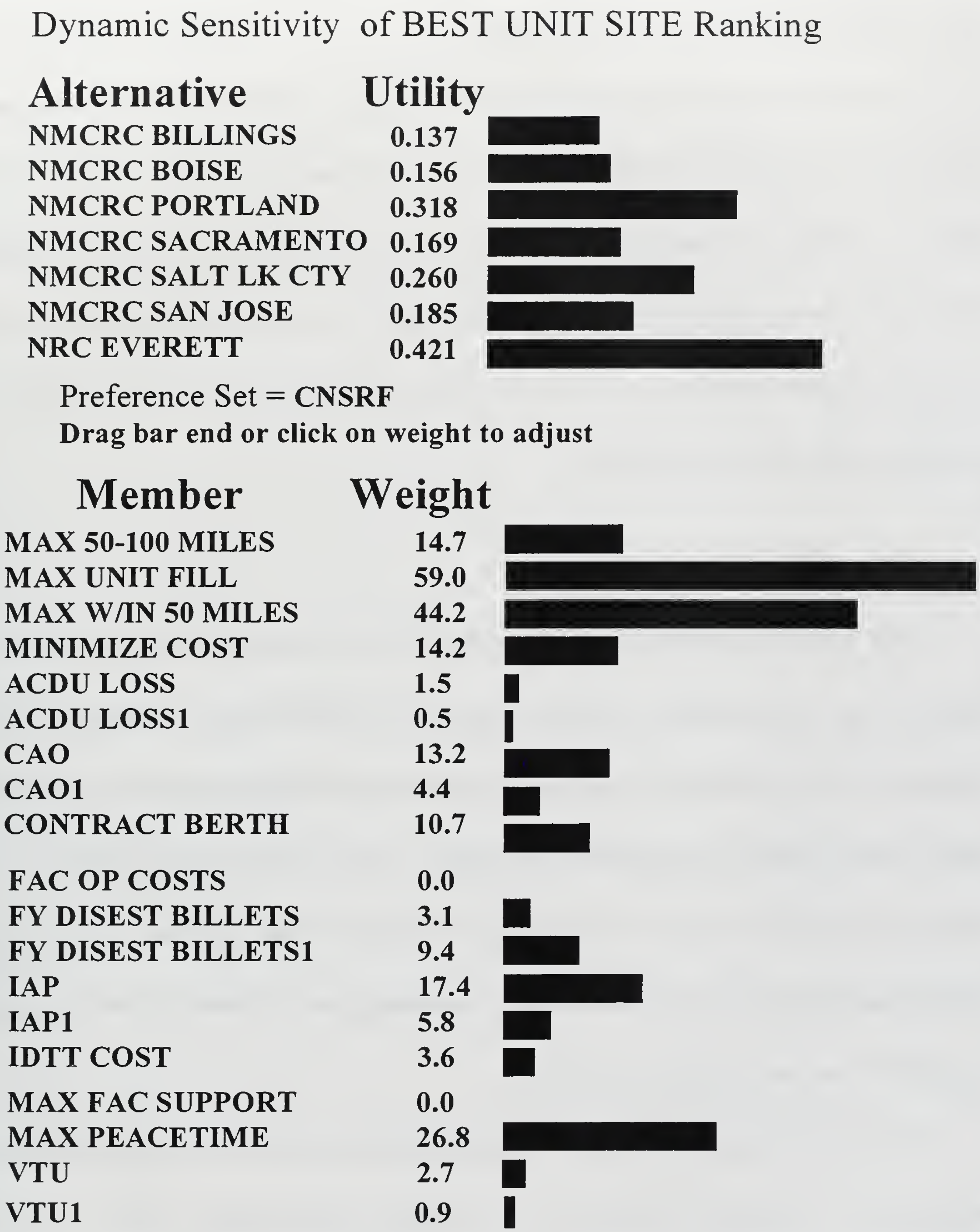

Figure 7. Dynamic Sensitivity Display

weight of a goal or measure in the lower pane and immediately see the effect on the utility of the alternatives in the upper pane.

One problem with the dynamic sensitivity display stems from the large number of alternatives in the unit location decision (i.e. 167 Reserve centers). Including all alternatives forces too much information into the sensitivity analysis display making it difficult to recognize the effect of changes. One way to handle this problem is to identify a smaller number (e.g. 5 to 8) of top ranking alternatives and conduct a sensitivity analysis on that subset.

D. CHAPTER SUMMARY

This chapter examines the DSS architecture by discussing three constituent phases of a unit location evaluation session: preprocessing, processing, and evaluation. Data extraction from various databases and data conversion to a single format occur during the preprocessing phase. Data manipulation, creation of a measures table of values, and importation of those values into the commercial decision model solver, occurs during the processing phase. Distance filtering using MapInfo™ also occurs during this phase.

During the evaluation phase, data are analyzed based on decision maker preferences. The result of this analysis is a ranking of alternatives. The reason for selecting Logical Decisions for Windows™ (LDW) as the decision model solver was

justified and the LDW displays that are expected to be of most use to the decision maker were explained.

V. CONCLUSIONS AND RECOMMENDATIONS

This thesis suggests an alternative to the current, intuitive process used by Commander, Naval Surface Reserve Force (COMNAVSURFRESFOR) when determining the most suitable location for Naval Reserve units. Complexity, multiple objectives, different decision perspectives, and large amounts of data can quickly overwhelm the cognitive abilities of the decision maker. The result is that the decision maker is forced to significantly limit the aspects considered, ignoring many factors that may affect the quality of the decision. Research to assist COMNAVSURFRESFOR improve the efficiency and effectiveness of the unit location decision supports the feasibility of a PC-based Decision Support System and the application of a formal decision model based on Multi-attribute Utility Theory.

Using decision analysis, objectives specified by COMNAVSURFRESFOR manpower specialists were decomposed into a hierarchy of goals and measures. General and specific assumptions and simplifications were made that limited the complexity of the model but maintained its validity as a representation of the real-world situation.

An important finding made during model development research was the limited number of automated databases or centralized data sources containing data required for the model. Although all required data were ultimately retrievable, it took numerous contacts to finally identify the offices maintaining various data source files.

Some data were identified as only available at field commands. Additionally, some data are not updated at regular intervals calling into question the accuracy over time of those factors in the decision analysis.

One advantage of a decision support system is its ability to reduce the time and manpower requirements involved in a decision process by extracting data from various databases with minimal input by the system operator. The data that are not available in automated databases must be manually entered into a decision support system. For the unit location model, most of this data can be archived after initial manual entry, requiring only periodic update. Significant reduction in the time required to thoroughly evaluate the alternatives is still possible, but an examination of COMNAVSURFRESFOR data management processes is recommended. Automated and centralized databases assist in maintaining updated accurate data, promote timely response to information requests, and reduce man-hours required for manual manipulation and storage of data. The benefit of such databases extends beyond the Reserve unit location decision.

Examining "ARIES: Army Reserve Installation Evaluation System," a prototype Spatial Decision Support System constructed for the Army Reserve supports the decision support system architecture proposed in this thesis. Follow on research into software design and constructing a prototype decision support system based on the decision model developed herein is recommended. However, even if the proposed

decision support system is not implemented, the insight gained by examining this decision model should assist the decision maker in improving the effectiveness of, providing a foundation for, and developing a consensus for Reserve unit location decisions.

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